

Testing Leptonic $SU(2)$ Horizontal Symmetry Using Neutrino Mixings

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(July, 2002)

Abstract

After some preliminary arguments suggesting that neutrino mixings with inverted mass pattern may be easier to understand within the framework of a local horizontal symmetry $SU(2)_H$ acting on leptons, we construct a specific extension of the minimal supersymmetric standard model that implements the idea and analyze its predictions. We show that the horizontal symmetry leads to an experimentally testable relation between the neutrino parameters U_{e3} and the ratio of solar and atmospheric mass difference squared i.e. $U_{e3}^2 \cos 2\theta_\odot = \frac{\Delta m_\odot^2}{2\Delta m_A^2} + O(U_{e3}^4, (m_e/m_\mu)^2)$. Taking the solar neutrino parameters inferred from present data at 99.7% confidence level, the above relation leads to a lower bound on $U_{e3} \geq 0.08$ and an allowed region in the U_{e3} and $\frac{\Delta m_\odot^2}{2\Delta m_A^2}$ space which can be tested in proposed long baseline experiments.

I. INTRODUCTION

As the outline of the neutrino mixings pattern is beginning to emerge from recent solar and atmospheric neutrino experiments, understanding the neutrino mass matrix has become one of the central problems in theoretical particle physics. On the phenomenological side, while the mixings responsible for both solar and atmospheric neutrino oscillations seem to be fairly large (unlike quark mixings) [1], the pattern of masses seem to remain undetermined. Three generic patterns that can be considered as equally acceptable at present are masses (i) with normal hierarchy i.e. $m_1 \ll m_2 \ll m_3$; (ii) inverted hierarchy i.e. $m_1 \simeq -m_2 \gg m_3$ and (iii) degenerate i.e. $m_1 \simeq m_2 \simeq m_3$. Once some of the contemplated long baseline neutrino experiments [2] and high precision searches for neutrinoless double beta decay [3] are carried out¹, the true mass pattern will be revealed. From a theoretical point of view, each pattern could be an indication of a different symmetry of physics beyond the standard model. Therefore, before those experiments are carried out, it is of interest in our opinion

¹If the recent reports of a positive signal for $\beta\beta_{0\nu}$ [4] are confirmed, the degenerate mass pattern [5] will be picked as the unique choice and models of the type discussed here will be disfavored.

to explore the symmetry approach to understanding neutrino masses and isolate their tests. Combination of the future experimental results and the theoretical explorations can then decide the nature of physics beyond the standard model.

The key issues that need to be understood are: (i) the large atmospheric and solar mixing angles; (ii) the smallness of the ratio $\Delta m_\odot^2/\Delta m_A^2$ and (iii) the smallness of the mixing U_{e3} .

One symmetry that predicts in zeroth order the correct mixing pattern i.e. large solar and atmospheric angles and zero U_{e3} is the combination of the three leptonic symmetries of the standard model i.e. $L_e - L_\mu - L_\tau$ [6]; it picks the inverted hierarchy pattern and an exact bimaximal mixing [7]. However in the symmetry limit it predicts that $\Delta m_\odot^2 = 0$ while Δm_A^2 is predicted to be nonzero. This, therefore raises the possibility that, one may be able to understand the second puzzle in such models. In fact if one includes small breakings of the $L_e - L_\mu - L_\tau$ symmetry either radiatively [8] or otherwise, it leads to quite interesting and testable neutrino mixing patterns. Because of this a great deal of attention has recently been focussed on it [6].

In order to have a deeper theoretical understanding of the inverted neutrino mass pattern with near bimaximal mixing or the $L_e - L_\mu - L_\tau$ symmetry, one approach would be to study it within a seesaw framework where the smallness of the neutrino masses is understood in a very simple manner [9]. It appears that the most convenient way to arrive at the inverted pattern with two large mixings in a seesaw framework is to work with two heavy right handed neutrinos rather than three as is dictated by quark lepton symmetry [10]. In a recent paper [11], we pointed out that if the standard model is extended by the inclusion of an $SU(2)_H$ [12] symmetry acting on two lepton families, freedom from global anomalies require that there be two right handed neutrinos at the scale where $SU(2)_H$ symmetry is broken. We further showed [11] that (i) the presence of the $SU(2)_H$ symmetry also helps in the understanding of the near bimaximal mixing pattern; (ii) the smallness of $\Delta m_\odot^2/\Delta m_A^2$ [13] is associated with a symmetry related to the horizontal symmetry. Needless to say that while it may appear that theory does not have quark lepton symmetry, it could be easily restored by including the third right handed neutrino and making it heavier than the seesaw scale. In this case the low energy theory near the horizontal symmetry breaking scale looks effectively like a theory with two right handed neutrinos.

It is the purpose of this paper to analyze this class of models in more detail and point out that in a specific supersymmetric realization of the model there is an experimentally interesting relation between the U_{e3} parameter, the ratio $\Delta m_\odot^2/\Delta m_A^2$ and the solar mixing angle θ_\odot i.e. $\sin\theta_\odot$ as follows: $U_{e3}^2 \cos 2\theta_\odot = \frac{\Delta m_\odot^2}{2\Delta m_A^2} + O(U_{e3}^4, (m_e/m_\mu)^2)$. Apart from being experimentally testable, this relation also provides a natural explanation of why the Δm_\odot^2 is so much smaller than Δm_A^2 .

We have organized this paper as follows: in section 2, we give arguments to suggest that within a seesaw framework for neutrino masses, normal or inverted hierarchical patterns prefer that one of the right handed neutrinos is much heavier than the others. In section 3, we present the basic ingredients of the model which is an $SU(2)_H$ extension of the minimal supersymmetric standard model (MSSM); in sec. 4, we discuss the predictions for neutrino mixings in the model and derive the main result of the paper, which is the relation between the neutrino oscillation parameters discussed above. Section 5 is devoted to some additional comments and in sec. 6, we give a summary of our results and conclusions.

II. WHY $SU(2)_H$?

In this section, we will argue that for the normal or inverted hierarchy case, it is quite possible that two of the right handed neutrinos are lighter than the third one. This can be seen as follows. Let us assume that the smallness of the neutrino masses owes its origin to the seesaw mechanism [9]:

$$\mathcal{M}_\nu = -M_D M_R^{-1} M_D^T \quad (1)$$

Inverting this relation with the assumption that the Dirac mass matrix is diagonal, one can express M_R in terms of the neutrino mixing matrix elements and the neutrino masses m_i and one has:

$$\mathcal{M}_{R,\alpha\beta} = m_{D,\alpha} \mu_{\alpha\beta}^{-1} m_{D,\beta} \quad (2)$$

with

$$\mu_{\alpha\beta}^{-1} = \sum_i U_{\alpha i} U_{\beta i} m_i^{-1} \quad (3)$$

where \mathbf{U} is the neutrino mixing matrix. Now observe that for both the normal and inverted hierarchy case, the lightest neutrino could have mass even equal to zero. Clearly as its mass gets closer to zero, the RH neutrino matrix takes the factorized form

$$M_R = m_1^{-1} |1\rangle \langle 1| \quad (4)$$

where $|1\rangle = (U_{11}m_{D1}^2, U_{21}m_{D1}m_{D2}, U_{31}m_{D1}m_{D3})$ and clearly the smaller m_1 is, the heavier the heaviest right handed neutrino becomes. On the other hand the masses of the other two RH neutrinos are not free since they are linked to observed Δm_\odot^2 and Δm_A^2 . In this sense, we see that for both the normal and the inverted hierarchy case, it is quite likely that there is a separation of the RH neutrino levels. In fact, in the case of inverted hierarchy, the two “heavy” left handed neutrinos are nearly degenerate, the two lighter RH neutrinos are likely to be very close in mass, which then makes the case for a symmetry associated with it. In ref. [11] we argued that the relevant symmetry is $SU(2)_H$ symmetry, which by group theory argument alone puts two of the RH neutrinos lighter than the third one. As discussed in ref. [11], this happens because, when the local horizontal symmetry acts on the charged right handed leptons, freedom from global anomalies indeed requires that there be two RH neutrinos transforming as a doublet under $SU(2)_H$. Their mass after $SU(2)_H$ symmetry breaking then would be of order of the horizontal symmetry breaking scale. The third RH neutrino being unconstrained by this symmetry would have a much higher mass.

III. DETAILS OF THE MODEL AND MASS MATRICES FOR LEPTONS

Our model is based on the gauge group $G_{STD} \times SU(2)_H$ with supersymmetry. In Table I the assignment of the leptons and Higgs superfields under the gauge group $SU(3)_c \times SU(2)_L \times U(1)_Y \times SU(2)_H \equiv G_{STD} \times SU(2)_H$ is given.

Table I

Particles	$G_{STD} \times SU(2)_H$ Quantum numbers
$\Psi \equiv (L_e, L_\mu)$	(1,2,-1,2)
L_τ	(1,2,-1,1)
$E^c \equiv (\mu^c, -e^c)$	(1,1,-2, 2)
τ^c	(1,1,-2, 1)
$N^c \equiv (\nu_\mu^c, -\nu_e^c)$	(1,1,0,2)
ν_τ^c	(1,1,0,1)
$\chi_H \equiv \begin{pmatrix} \chi_1 & \chi_2 \end{pmatrix}$	(1, 1, 0, 2)
$\bar{\chi}_H \equiv (\bar{\chi}_1, \bar{\chi}_2)$	(1,1,0,2)
H_u	(1,2,1,1)
H_d	(1,2,-1,1)
Δ_H	(1,1,0,3)

Table caption: Representation content of the various fields in the model under the gauge group $G_{STD} \times SU(2)_H$.

Here $L_{e,\mu,\tau}$ denote the left handed lepton doublet superfields. The quarks can transform as singlets or doublets of $SU(2)_H$ and are not mentioned since it does not mix affect the lepton masses which is the main focus of this paper. We arrange the Higgs potential in such a way that the $SU(2)_H$ symmetry is broken by $\langle \chi_1 \rangle = v_{H1}$; $\langle \chi_2 \rangle = v_{H2}$ and $\langle \Delta_{H,3} \rangle = v'_H$, where $v_H, v'_H \gg v_{wk}$. Note that we have used the $SU(2)_H$ symmetry to align the Δ_H vev along the $I_{H,3}$ direction. At the weak scale, the neutral components of the fields H_u and H_d acquire nonzero vev's and break the standard model symmetry down to $SU(3)_c \times U(1)_{em}$. We denote these vev's as follows: $\langle H_u^0 \rangle = \kappa_0$ and $\langle H_d^0 \rangle = \kappa_0 \cot \beta$; Clearly κ_0 is expected to have values in few to 100 GeV range. All the vev's and couplings are taken to be real.

Note that $\langle \Delta_H \rangle \neq 0$ breaks the $SU(2)_H$ group down to the $U(1)_{L_e-L_\mu}$ group which is further broken down by the χ_H vev. Since the renormalizable Yukawa interactions do not involve the χ_H field, this symmetry ($L_e - L_\mu$) is also reflected in the right handed neutrino mass matrix and plays a role in leading to the bimaximal mixing pattern.

To study the pattern of neutrino masses and mixings, let us first note that if we included $\nu_{\tau R}$ in the theory, a bare mass for the $\nu_{\tau,R}$ field is allowed at the tree level unconstrained by any symmetries. This mass can therefore be arbitrarily large and $\nu_{\tau,R}$ will decouple from the low energy spectrum. We will work in this limit of decoupled $\nu_{\tau R}$ and write down the gauge invariant Yukawa superpotential involving the remaining leptonic fields.

$$\begin{aligned}
\mathcal{W}_Y = & h_1(L_e H_u \nu_e^c + L_\mu H_u \nu_\mu^c) + h_0 L_\tau (\nu_\mu^c \chi_2 + \nu_e^c \chi_1) H_u / M \\
& - i f N^{cT} \tau_2 \tau \cdot \Delta_H N^c + \frac{h'_1}{M} (L_e \chi_2 - L_\mu \chi_1) H_d \tau^c \\
& + \frac{h'_4}{M} L_\tau H_d (\mu^c \chi_2 + e^c \chi_1) + h'_3 L_\tau H_d \tau^c + h'_2 (L_e e^c + L_\mu \mu^c) H_d
\end{aligned} \tag{5}$$

$\langle \Delta_H^0 \rangle = v'_H$ directly leads to the $L_e - L_\mu$ invariant $\nu_{eR} - \nu_{\mu R}$ mass matrix at the seesaw scale. The χ_H vev contributes to this mass matrix only through nonrenormalizable operators and we assume those contributions to be negligible. We also do not include any term where Δ_H and $\bar{\chi}_H$ couple to light fields. Since in supersymmetric theories, the superpotential does not receive any loop induced corrections due to the nonrenormalization theorem, conclusions derived on the basis of the above potential are stable under radiative corrections. It must however be noted that even if such couplings were allowed, there would be no change in the predictions since the effects would be small. Similarly there will also be some small contributions from the $\nu_{\tau R}$ sector if we did not decouple it completely. We ignore these contributions in our analysis. Further, we define $\kappa_{1,2} = \frac{\langle \chi_{1,2} \rangle \kappa_0}{M}$ taken to be of order 10 GeV or so.

To study neutrino mixings, we write down the 5×5 seesaw matrix for neutrinos:

$$M_{\nu_L, \nu_R} = \begin{pmatrix} 0 & 0 & 0 & h_0 \kappa_0 & 0 \\ 0 & 0 & 0 & 0 & h_0 \kappa_0 \\ 0 & 0 & 0 & h_1 \kappa_1 & h_1 \kappa_2 \\ h_0 \kappa_0 & 0 & h_1 \kappa_1 & 0 & f v'_H \\ 0 & h_0 \kappa_0 & h_1 \kappa_2 & f v'_H & 0 \end{pmatrix} \quad (6)$$

After seesaw diagonalization, it leads to the light neutrino mass matrix of the form:

$$\mathcal{M}_\nu = -M_D M_R^{-1} M_D^T \quad (7)$$

where $M_D = \begin{pmatrix} h_0 \kappa_0 & 0 \\ 0 & h_0 \kappa_0 \\ h_1 \kappa_1 & h_1 \kappa_2 \end{pmatrix}$; $M_R^{-1} = \frac{1}{f v'_H} \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$. The resulting light Majorana neutrino mass matrix \mathcal{M}_ν is given by:

$$\mathcal{M}_\nu = -\frac{1}{f v'_H} \begin{pmatrix} 0 & (h_0 \kappa_0)^2 & h_0 h_1 \kappa_0 \kappa_2 \\ (h_0 \kappa_0)^2 & 0 & h_0 h_1 \kappa_0 \kappa_1 \\ h_0 h_1 \kappa_0 \kappa_2 & h_0 h_1 \kappa_0 \kappa_1 & 2 h_1^2 \kappa_1 \kappa_2 \end{pmatrix} \quad (8)$$

To get the physical neutrino mixings, we also need the charged lepton mass matrix defined by $\bar{\psi}_L \mathcal{M}_\ell \psi_R$. This is given in our model by:

$$\mathcal{M}_\ell = \cot \beta \begin{pmatrix} h'_2 \kappa_0 & 0 & -h'_1 \kappa_2 \\ 0 & h'_2 \kappa_0 & h'_1 \kappa_1 \\ h'_4 \kappa_1 & h'_4 \kappa_2 & h'_3 \kappa_0 \end{pmatrix} \quad (9)$$

In order to study physical neutrino mixings, we must diagonalize the \mathcal{M}_ν and \mathcal{M}_ℓ matrices. We discuss this in the next section.

IV. A RELATION BETWEEN NEUTRINO MIXINGS AND SMALLNESS OF $\Delta M_\odot^2 / \Delta M_A^2$

In order to discuss the physical neutrino mixings, we need to work in a basis where the charged lepton mass matrix is diagonal. Defining the matrices that diagonalize the charged lepton mass matrix as $D_\ell = U_\ell^{(L)} M_\ell U_\ell^{(R)\dagger}$, we get

$$U_\ell^{(L)} = \begin{pmatrix} s_1 & c_1 & 0 \\ c_\beta c_1 & -c_\beta s_1 & s_\beta \\ -s_\beta c_1 & s_\beta s_1 & c_\beta \end{pmatrix} \quad (10)$$

where $\tan 2\beta \simeq 2\sqrt{\frac{h'_1}{h'_4}}\sqrt{m_\mu/m_\tau}$ and $\sin\theta_1 \equiv s_1 = \frac{\kappa_1}{\sqrt{\kappa_1^2 + \kappa_2^2}}$. This matrix receives small corrections of order m_e/m_μ , which are not important for our considerations.

In order to discuss neutrino mixings, we write down the orthogonal matrix U_ν that diagonalizes the \mathcal{M}_ν for $\kappa_1 \neq 0$. Defining two angles $\theta_{1,2}$:

$$\begin{aligned} \sin\theta_1 &\equiv s_1 = \frac{\kappa_1}{\sqrt{\kappa_1^2 + \kappa_2^2}} \\ \sin\theta_2 &\equiv s_2 = \frac{h_0\kappa_0}{\sqrt{h_0^2\kappa_0^2 + h_1^2(\kappa_1^2 + \kappa_2^2)}} \end{aligned} \quad (11)$$

the neutrino mass matrix can be written in terms of these angles as:

$$\mathcal{M}_\nu = \sqrt{\Delta m_A^2} \begin{pmatrix} 0 & s_2^2 & c_2 s_2 c_1 \\ s_2^2 & 0 & c_2 s_2 s_1 \\ c_2 s_2 c_1 & c_2 s_2 s_1 & 2c_2^2 s_1 c_1 \end{pmatrix} \quad (12)$$

The neutrino mass matrix \mathcal{M}_ν has a zero eigenvalue since one of the three right handed neutrinos was not protected by the $SU(2)_H$ symmetry and had decoupled. Identifying this with the third neutrino we have its mass $m_3 = 0$. The corresponding third-neutrino eigenvector is easy to evaluate exactly and is $(c_2 s_1, c_2 c_1, -s_2)$.

The orthogonal matrix that diagonalizes \mathcal{M}_ν (i.e. $U_\nu^\dagger \mathcal{M}_\nu U_\nu = D_\nu$) is given by

$$U_\nu = \begin{pmatrix} c_1 c' - s_1 s_2 s' & c_1 s' + s_1 s_2 c' & c_2 s_1 \\ -s_1 c' - c_1 s_2 s' & -s_1 s' + c_1 s_2 c' & c_2 c_1 \\ -c_2 s' & c_2 c' & -s_2 \end{pmatrix} \quad (13)$$

where $s' = \sin\theta'$ with θ' given by $\tan 2\theta' = \frac{2s_2(c_1^2 - s_1^2)}{(1 + s_2^2)2s_1 c_1}$. Note that as $s_1 \rightarrow 0$, $\theta' \rightarrow \pi/4$. Note that the third neutrino eigenvector is the third column of the above matrix.

The final physical neutrino mixing matrix is then given by $\mathbf{U} = U_\ell^{(L)} U_\nu$, where $U_\ell^{(L)}$ is defined in the previous section. Combining this with the neutrino mixing matrix U_ν , we get the final physical neutrino mixing matrix U to be

$$\mathbf{U} = \begin{pmatrix} s_2 s' & s_2 c' & c_2 \\ -(c' c_\beta + c_2 s' s_\beta) & -(c_\beta s' - s_\beta c_2 c') & -s_2 s_\beta \\ (c' s_\beta - c_2 s' c_\beta) & (c_2 c' c_\beta + s' s_\beta) & s_2 c_\beta \end{pmatrix} \quad (14)$$

To see the consistency of the model, we first note that $U_{e3} = c_2 \leq 0.16$ from the reactor neutrino data [14]. This implies $s_2 \simeq 1$ and for $\kappa_1 \ll \kappa_2 \ll \kappa_0$, $\frac{h_1 \kappa_2}{h_0 \kappa_0} \leq 0.16$. To fit the atmospheric data, we then require, $s_\beta \simeq 1/\sqrt{2}$. This can be easily satisfied by requiring the Yukawa couplings to have a hierarchy $h'_4/h'_1 \ll 2\sqrt{\frac{m_\mu}{m_\tau}}$.

The solar mixing angle ($\sin\theta_\odot \equiv U_{e2}$), for $s_2 \simeq 1$ is given by

$$\tan 2\theta_\odot \equiv \tan 2\theta' \simeq \cot 2\theta_1 \quad (15)$$

This implies that

$$\sin 2\theta_\odot \simeq (c_1^2 - s_1^2) = \frac{\kappa_2^2 - \kappa_1^2}{\kappa_2^2 + \kappa_1^2} \quad (16)$$

Coming to neutrino masses m_1, m_2 and m_3 , in the absence of $\kappa_1\kappa_2$ we have $m_1 = -m_2 = h_0\kappa_0$ and $m_3 = 0$. The solar mass squared difference $\Delta m_\odot^2 = m_1^2 - m_2^2$ is generated when κ_1 is turned on while the atmospheric mass squared difference $\Delta m_A^2 \equiv m_1^2 - m_2^2 \simeq h_0^2\kappa_0^2$ gets a small correction. In the limit of $s_2 \simeq 1$, one can write Δm_\odot^2 in terms of κ_i as follows:

$$\frac{\Delta m_\odot^2}{\Delta m_A^2} = \frac{4h_1^2\kappa_1\kappa_2}{\sqrt{h_0^2\kappa_0^2 + h_1^2(\kappa_1^2 + \kappa_2^2)}} \quad (17)$$

It is then clear that if we choose $\kappa_{1,2} \ll \kappa_0$ along with a mild hierarchy among the Yukawa parameters $h_{1,0}$, we can obtain the desired solar neutrino mass squared difference. This leaves the relative value of κ_1 with respect to κ_2 unaffected. Appropriately choosing their relative values, we can get the solar mixing angle to be smaller than maximal as indicated by the central value for it.

Combining the above equations, we get for $U_{e3} \ll 1$,

$$U_{e3}^2 \cos 2\theta_\odot = \frac{\Delta m_\odot^2}{2\Delta m_A^2} + O(U_{e3}^4, (m_e/m_\mu)^2) \quad (18)$$

This equation is the major result of the paper and it is a direct consequence of the $SU(2)_H$ symmetry. It is interesting to note that the smallness of $\Delta m_\odot^2/\Delta m_A^2$ is related to the smallness of U_{e3} . Furthermore this relation, Eq.(20) provides a test of the leptonic horizontal symmetry. In Fig. 1, we show the implications of this equation for the allowed parameter range in the case of the LMA solution to the solar neutrino problem. Inside of the quadrilateral is the allowed region for the parameters for the central value of the $\Delta m_A^2 = 2.5 \times 10^{-3} \text{ eV}^2$. Therefore, unless new solar neutrino data changes the current picture of neutrino mixings, long base line experiments such as the proposed JHF and NUMI Off-axis [15] as well as KAMLAND experiments must yield points inside this allowed region, if this model is to describe nature. As is clear from the Fig. 1, taking the best fit values for the solar mixing angle i.e. $0.22 \leq \tan^2\theta_\odot \leq 0.59$ and $2.2 \times 10^{-5} \text{ eV}^2 \leq \Delta m_\odot^2 \leq 2 \times 10^{-4} \text{ eV}^2$ (at 99.7% c.l.), we find that, $0.25 \leq \cos 2\theta_\odot \leq 0.63$, and using the above equation we get,

$$0.4 \geq U_{e3} \geq 0.083 \quad (19)$$

Thus this model is testable in near future.

V. COMMENTS AND OTHER TESTS OF THE MODEL

(i) A characteristic test of the inverted hierarchy models is in its prediction for neutrinoless double beta decay [16]. Generically in the exact bimaximal limit, the effective mass measured in neutrinoless double beta decay i.e. $\langle m \rangle_{\beta\beta} \equiv \sum U_{ei}^2 m_i = 0$, since we have

$\langle m \rangle_{\beta\beta} = m_1 U_{e1}^2 + m_2 U_{e2}^2$ and $m_1 = -m_2$ and $U_{e1} = U_{e2} = 1/\sqrt{2}$. The mass matrix in Eq. (8) however differs from this limit; nonetheless, the change in mass differences and the change in the mixing angles compensate each other to give zero. Therefore in the class of models we are discussing, the neutrinoless double beta decay is a probe of the structure of the leptonic mass matrix. In our case we predict $\langle m \rangle_{\beta\beta} \simeq (\cos 2\theta_\odot \sqrt{\Delta m_A^2})$, which at 99.7% confidence level be as large as 0.03 eV.

(ii) The model leads to the standard MSSM below the horizontal symmetry breaking scale.

(iii) In our model we imposed $\bar{\chi} \rightarrow -\bar{\chi}$ discrete symmetry. This will leave the charge neutral Higgsinos corresponding to χ and $\bar{\chi}$ massless. However one may add a bilinear term of the form $\bar{\chi}\chi$ to the superpotential thereby breaking the discrete symmetry softly. This will then generate a mass for the corresponding horizontal Higgsino.

VI. SUMMARY AND CONCLUSIONS

In conclusion, we have presented an extension of the minimal supersymmetric standard model where a local $SU(2)_H$ symmetry acts on both on the left and right handed charged leptons. Freedom from global anomalies then requires that a doublet of right handed neutrinos be included in the theory. This model provides a very natural way to understand two crucial features of the current neutrino oscillation data i.e. near bimaximal mixing pattern and a small $\Delta m_\odot^2/\Delta m_A^2$. It also gives a relation between the neutrino observables U_{e3} , $\Delta m_\odot^2/\Delta m_A^2$ and solar mixing angle $\sin^2 2\theta_\odot$. For the current fits to the latter two parameters, it predicts a lower bound on U_{e3} which is quite accessible to long baseline experiments currently planned. We also present the complete range of allowed values for U_{e3} and $\Delta m_\odot^2/\Delta m_A^2$ predicted by our model.

The work of R. N. M. is supported by the National Science Foundation Grant No. PHY-0099544. We thank Luis Lavoura for a useful comment and Dragos Constantin for help with the figure.

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